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February 18, 2009

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RE: United States v. Buckeye Egg Farm, L.P., et al. – Civil Action 3:03 CV 7681. Final Report of the Distiller's Dried Grains with Solubles and Best Management Practices for Ohio Fresh Eggs' Mt. Victory Facility

Dear Sir/Madam:

As required under Attachment A of the Consent Decree in the above-referenced matter, I have enclosed a copy of the Final Report of the Test of the Effects of the Distiller's Dried Grains with Solubles and Best Management Practices on Ammonia Emissions from a High-Rise Layer

Barn for Ohio Fresh Eggs' Mt. Victory Facility. Also enclosed is Ohio Fresh Eggs' Certification for this Report.

Should you need additional information, please contact me. Thank you for your consideration of this matter.

Very truly yours,

KEATING MUETHING & KLEKAMP PLL

By: Brian Babb
Brian M. Babb

Enclosures

cc: Mr. John Glessner
Dr. Albert J. Heber
Mr. Donald Hershey

BMB:llm

CERTIFICATION

I certify under penalty of law that this document and any attachments to it were prepared under my direction or supervision in accordance with a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing and willful submission of a materially false statement.

OHIO FRESH EGGS, LLC

John W. Glessner, Jr., Chief Executive Officer

2843659.1

Effects of Distiller's Dried Grains with Solubles and Best Management Practices on Ammonia Emissions from a High-Rise Layer Barn

Final Report

to

Ohio Fresh Eggs, LLC
11212 Croton Road, Croton, OH 43013

by

Teng Teeh Lim, Albert J. Heber, Ji-Qin Ni, and Samuel M. Hanni

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February 17, 2009

Effects of Distiller's Dried Grains with Solubles and Best Management Practices on Ammonia Emissions from a High-Rise Layer Barn

Teng Teeh Lim, Albert J. Heber, Ji-Qin Ni, and Samuel M. Hanni

Abstract

Ammonia (NH_3) emission rates were measured at two large high-rise layer barns (Barns 1 and 2) that are owned by Ohio Fresh Eggs, LLC. The tests were conducted at the Mt. Victory facilities, to evaluate baseline and mitigated emission rates, as required by a federal consent decree. Continuous emission data was collected from August 1, 2007 to March 17, 2008. The tests included the applications of distiller's dried grains with solubles (DDGS) in a fiber-enhanced diet, and a suite of best management practices (BMPs). The DDGS feed and the BMPs were implemented on August 6, 2007, in Barn 2, and tested for effectiveness of mitigating NH_3 emissions. The emission rate of untreated Barn 1 was measured for comparison purposes. The BMPs included the operation of 36 drying fans in the manure pit; a reduced crude protein feed ration; reduced chlorine in the feed ration; improved waterline leak management practices; and a lower bird density. Concentrations of NH_3 were measured at the barn exhaust fans and in ambient air using photoacoustic and chemiluminescence analyzers. The average outdoor temperature over the seven-month period was 8.6°C. The average daily mean (ADM) untreated NH_3 emission rates of B1 was 4376 mg/s. When normalized to animal live mass, the ADM untreated NH_3 emission rate was 729 g d^{-1} AU^{-1} (2.21 g d^{-1} hen^{-1}), where AU is the animal unit (500 kg live mass). When the fiber-enhanced diets and BMPs were implemented, the mean paired difference of NH_3 emission between the two barns was 72% (n=90 out of 105 days). When the fiber-enhanced diet was discontinued, while still keeping all the BMPs, the NH_3 emission reduction averaged 64%, between December 11, 2007 and January 14, 2008. However, the reduction during this test period could not be entirely attributed to the BMPs because of manure remaining in the treated barn from previous test. Effects of BMPs were evaluated again after manure removal and pit re-bedding was conducted during the last test period, and it was concluded that the BMPs had reduced emission rate by 55%. The pit drying fans and the leakage management program were effective in reducing manure moisture control (MC).

Introduction

This test report contains data collected from the egg production facilities located near LaRue, Hardin County, Ohio ("Mt. Victory Facilities"). The study was conducted to evaluate the effectiveness of an enhanced fiber diet, and several best management practices (BMPs), in reducing ammonia (NH_3) emission rates. The Facilities are subject to the requirements of the Consent Decree in *United States vs. Buckeye Egg Farm, L.P., et al.,* United States District Court, Northern District of Ohio, Western Division, Civil Action No. 3:03CV7681.

Continuous NH_3 emission data was collected to study the effectiveness of several emission abatements. The tests included the application of distiller's dried grains with solubles (DDGS) in an enhanced fiber diet, and several BMPs. The DDGS feed and

BMPs were introduced on August 6, 2007 in Barn 2 (B2), while Barn 1 (B1) served as the untreated barn for comparison. An on-farm instrument shelter (OFIS) was used to house instruments to measure NH_3 emissions from the two mechanically-ventilated barns.

This 2007-2008 test was conducted by Mr. Sam Hanni, with supervision and oversight by Drs. Albert Heber and Teng Lim, Purdue University. This was the first test of DDGS and BMPs for NH_3 emission mitigation ever conducted in a large layer barn. The objective of the test was to determine the effectiveness and potential of DDGS and BMPs in reducing NH_3 emissions from high-rise layer barns.

Methods and Procedure

Description of Laying Barn

The two caged-hen layer barns at Mt. Victory, Ohio (20449 County Rd 245, Mt Victory, OH 43340) were built in 1994, along with 12 other barns at the facility. The barns are 201 meters (m) x 20.7 m, oriented E-W, and spaced 20.7 m apart. Barns 1 and 2 housed about 172,000 and 154,000 hens in eight rows of 4-tier crates in the 3.3-m high upper floor. Manure was scraped off boards under the cages into the 3.2-m high first floor. Manure drying on the first floor was enhanced with eighteen, 918-mm dia. auxiliary circulation fans (Model VG36DM3F, J&D Manufacturing, Eau Claire, WI).

Experimental Design

The tests conducted include the application of DDGS in an enhanced fiber diet, and several BMPs. Continuous emission data was collected from August 1, 2007 to March 17, 2008. The DDGS feed and the BMPs were introduced on August 6, 2007. The test was scheduled to start on July 1, 2007, but was delayed until August 1, 2007, because of incomplete manure removal and because the data acquisition system was damaged by a lightning strike. Manure could not be removed from both barns due to scheduling (land application of manure is often conducted in Spring and Fall), weather, and very wet ground. The DDGS feed and the BMPs were introduced on Monday, August 6, 2007, after the data acquisition system was repaired on July 31, 2007.

The BMPs implemented in this test include:
1) operation of 36 drying fans in the manure pit;
2) reduction in the amount of crude protein in the feed ration;
3) reduction of amount of chlorine in the feed ration;
4) implementation of improved waterline leak management practices; and
5) reducing bird density in the barn.

The enhanced fiber diet and BMPs were implemented in B2, while B1 was the control (untreated) barn. Both barns had similar ages of birds and weights. Manure was completely removed on July 9, 2007 and both barns were re-bedded with same amount of manure. Regulatorily required manure turning (only when the piles were low enough for the turner) was not suspended in this test. Field tests of fan performance were conducted on October 3 to 5, 2007 and the results were included in the emission rate calculations.

Several tests were conducted during the eight months of tests. The test schedule and descriptions are listed in Table 1. In Test 1, no abatement was applied, except for the lower hen numbers in B2. The fiber-enhanced (DDGS) diet and above-mentioned BMPs were implemented in B2 from August 6 until December 10, 2007. However, the first three weeks of data was grouped into Test 2 to allow the diet and BMPs to take effect and changes in the emission rates to stabilize. A 15-week period was allocated to study the effectiveness of both DDGS diet and BMPs in Test 3. In Test 4, the normal diet ration was resumed in B2, while keeping the BMPs. Manure was removed from January 15 to February 18, 2008, thus, data of Test 5 was excluded for evaluating effectiveness. After both barns were re-bedded with similar amounts and characteristics of manure, the effectiveness of BMPs was again tested in B2, in Test 6, until March 17, 2008.

Table 1. Tests conducted during study.

Test	Date	Description
1	8/1-8/6	Baseline with reduced bird density
2	8/7-8/27	Stabilizing period
3	8/28-12/10	DDGS + BMPs
4	12/11-1/14	BMPs only, old manure
5	1/15-2/18	Manure removal
6	2/19-3/17	BMPs only, new manure

Instrument Shelter and Environmental Variable Measurement

An air-conditioned trailer was kept at the site for this test for the measurement equipment, data acquisition and control (DAC) software and hardware, environmental variable analyzers, including differential pressure, thermocouples (Type T), relative humidity (RH) and temperature (T) probes.

The fan airflow capacities were measured on October 3 to 5, 2007, with a calibrated portable fan tester that consisted of multiple traversing impeller anemometers (Gates et al., 2004).

Ammonia Concentration Measurement

Ammonia concentrations were measured with a chemiluminescence (CL) NH_3 analyzer (Model 17C, Thermo Fisher Scientific, Waltham, MA), after conversion to nitric oxide. The analyzer sampled air at a flow rate of 0.6 L/min with an external vacuum pump (Model PU426, KNF Neuberger, Trenton, NJ). A photo-acoustic infrared (PIR) NH_3 monitor (Mine Safety Appliances, Pittsburgh, PA) was collocated with the CL method for the barn measurements. Each NH_3 analyzer was checked or calibrated (when needed) with standard zero and span gases at least twice per week.

A photoacoustic infrared, multi-gas monitor (INNOVA Model 1412, Innova AirTech Instruments, Ballerup, Denmark) was used in place of the MSA monitor, from August 1 to 28, 2007 when the MSA monitor was malfunctioning.

Manure and Feed Sampling and Analysis

Twenty-four manure samples were collected from randomly selected locations in each barn. Two composite feed samples were taken from the front end of the feeders in each barn. Each of the feed samples consisted of subsamples taken from the feeders of either the western or the eastern half of the barns. After collection, the samples were put on ice and delivered to the Purdue Agricultural Air Quality Laboratory for storage (kept frozen), and sent to the Midwest Laboratories (Omaha, Nebraska) for analysis. The manure was analyzed for moisture content (MC) and pH, while the feed samples were analyzed for MC, crude protein, fat, and fiber, and other variables including ash, sulfur, phosphorus, and calcium contents.

Results

This report includes results of tests collected from August 1, 2007 to March 17, 2008. All of the reported average daily mean (ADM) or daily/hourly mean values consisted of over 70% valid data (complete-data days or complete-data hours) to avoid biasness due to missing data. The data completeness values for barn NH_3 emission, in terms of the number of days with over 70% valid data, were 92% and 90% for B1 and B2, respectively. The longest incomplete data period was 6 days in early October, 2007 caused by malfunctioning data acquisition, which was about 2.6% of the 230 measurement days.

The NH_3 concentration measurement was conducted using photoacoustic (INNOVA and Mine Safety Appliances units) and chemiluminescence analyzers. The emission data reported in this report are calculated based on the photoacoustic analyzers for more complete data. The original upper measurement range of the chemiluminescence analyzer was only 100 ppm, while the barn exhaust concentrations often exceeded 200 ppm in this test, especially in the cold months when barn airflow was low.

The basic statistics of important variables, including barn inventory, environment variables, and ADM emission values are reported in Tables 2 and 3. The monitoring test started with 177,496 and 155,616 hens, and ended with 167,708 and 151,318 hens in B1 and B2, respectively (Figure 1). The hens were of similar age, and no flock change occurred in this test period. The ADM bird mass was 1.51 kg for B1, and was 1.41 kg for B2. The ADM total live masses of B1 and B2 were 518 and 433 AU (AU=500 kg live mass), respectively, Figure 1.

Table 2. Summary of Daily Means for Barn 1 from 8/1/2007 to 3/17/2008.

Parameter	n	Min	Mean	Max	SD
Bird inventory, n	231	168,113	172,110	177,496	2231
Mean bird mass, kg/bird	231	1.43	1.51	1.55	0.03
Total live mass, AU	231	501	518	532	6.87
Temperatures, °C					
Ambient air	223	-12.5	8.61	30.2	11.24
Cages	223	16.0	22.4	31.2	2.95
Exhaust air	223	12.1	19.9	31.3	4.32
Airflow, dsm³/s	220	40.9	157	390	121
Ammonia Concentration and Emission Rate					
Ambient conc., ppm	218	-3.86	3.43	12.02	2.89
Exhaust conc., ppm	216	9.07	72.3	165	41.8
Net emission, mg/s	211	1,092	4376	8,593	1668
Net emission, g d^{-1} AU^{-1}	211	185	729	1433	277
Net emission, g d^{-1} hen^{-1}	211	0.55	2.21	4.39	0.86

Table 3. Summary of Daily Means for Barn 2 from 8/1/2007 to 3/17/2008.

Parameter	n	Min	Mean	Max	SD
Bird inventory, n	231	151,520	153,538	155,616	1111
Mean bird mass, kg/bird	231	1.36	1.41	1.45	0.03
Total live mass, AU	231	422	433	442	5.6
Temperatures, °C					
Cages	223	16.7	22.4	30.7	2.38
Exhaust air	223	9.94	19.9	31.1	4.45
Airflow, dsm³/s	220	31.0	121	385	120
Ammonia Concentration and Emission Rate					
Ambient conc., ppm	218	-3.86	3.43	12.0	2.89
Exhaust conc., ppm	208	8.78	53.1	192	42.2
Net emission, mg/s	206	556	1801	5,499	1084
Net emission, g d^{-1} AU^{-1}	206	113	359	1107	215
Net emission, g d^{-1} hen^{-1}	206	0.31	1.02	3.12	0.62

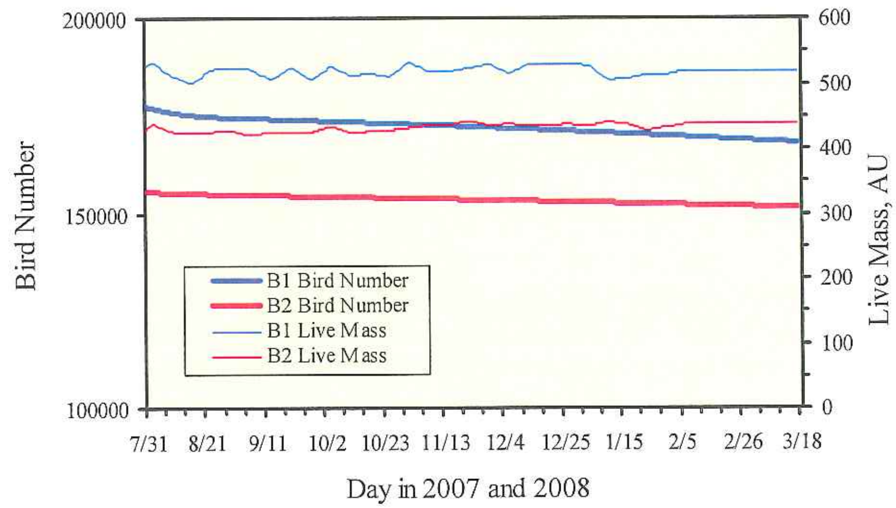

Figure 1. Bird number and total live mass.

The ADM airflow rates of B1 and B2 were 157 and 121 dsm³/s, respectively. As expected, barn ventilation rates were generally higher in warm weather (Figure 2). Except for a few days when the barn ventilation capacity was reached in both barns (until September 12, 2007), the B2 airflow was lower than B1, because more airflow was required (to provide cooling) for the greater number of layers in B1. The ADM ambient temperature was 8.6°C (daily means ranged from -12.5°C to 30.2°C), while the historical mean annual local temperature is 10.0°C. The ADM ambient temperature was 1.4°C lower than the local mean annual temperature, thus this data set represents cooler than average weather. Similar to previous studies (Lim et al., 2007), close correlation between the ambient temperature and barn airflow rate was also observed in this study. A paired t-test was conducted to examine the barn ventilation rates, and indicated that the two were significantly different ($P<0.01$).

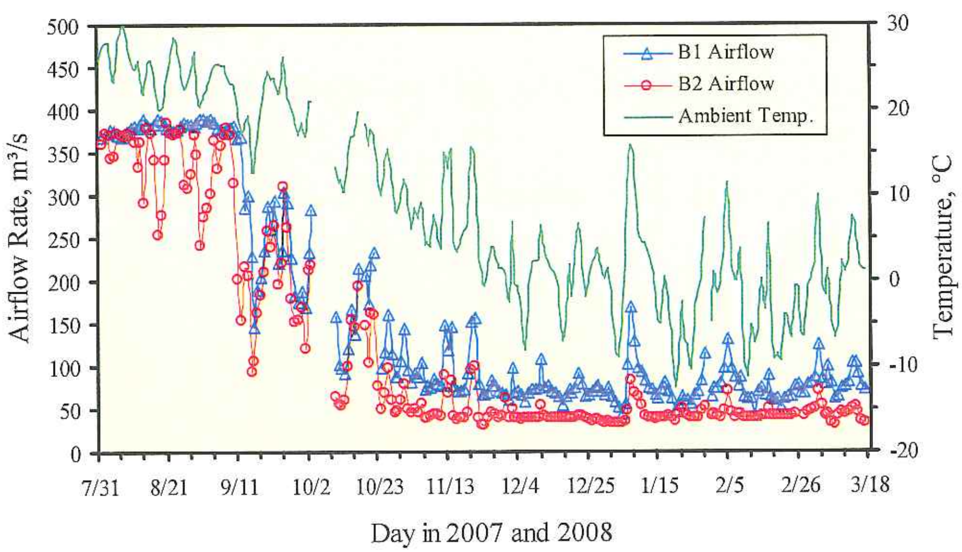

Figure 2. Barn ventilation rate and ambient temperature.

The daily mean barn (cage level) and pit exhaust temperatures are presented in Figure 3. The ADM cage temperatures (centers of cages, three points along the barn length) were 22.4°C for both B1 and B2, respectively, and were not statistically different based on a paired t-test (P=0.78). However, the cage level B2 temperatures were maintained generally lower in the month of October 2007, and higher after late December 2007. The ADM exhaust temperatures (up to six sampling locations) averaged 19.9°C for both B1 and B2.

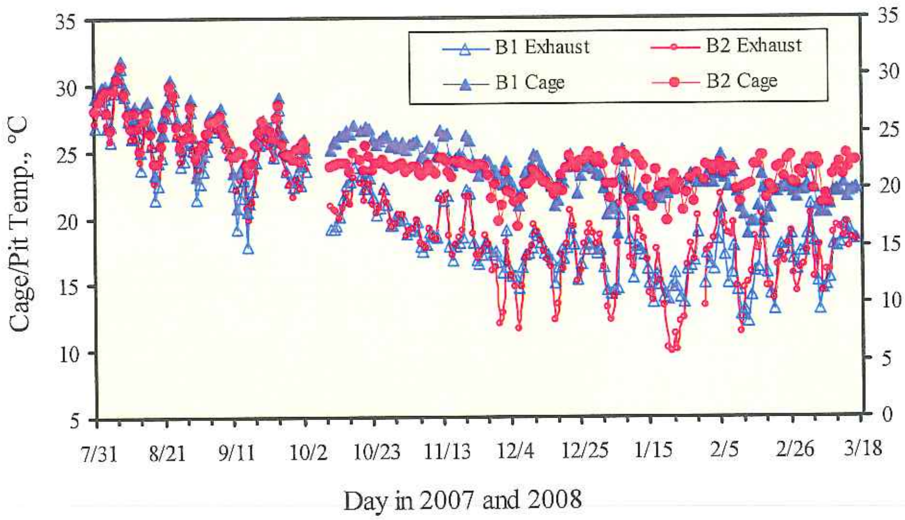

Figure 3. Daily mean cage and pit exhaust temperatures

Daily mean exhaust air relative humidity (RH) ranged from 43% to 87% and 44% to 91% for B1 and B2, respectively, while the ambient RH ranged from 48% to 98% (Figure 4). The ADM RH was 77% for ambient air, and 67% and 69% for B1 and B2, respectively. The ADM cage RH of B1 was 69%, and was 75% for B2.

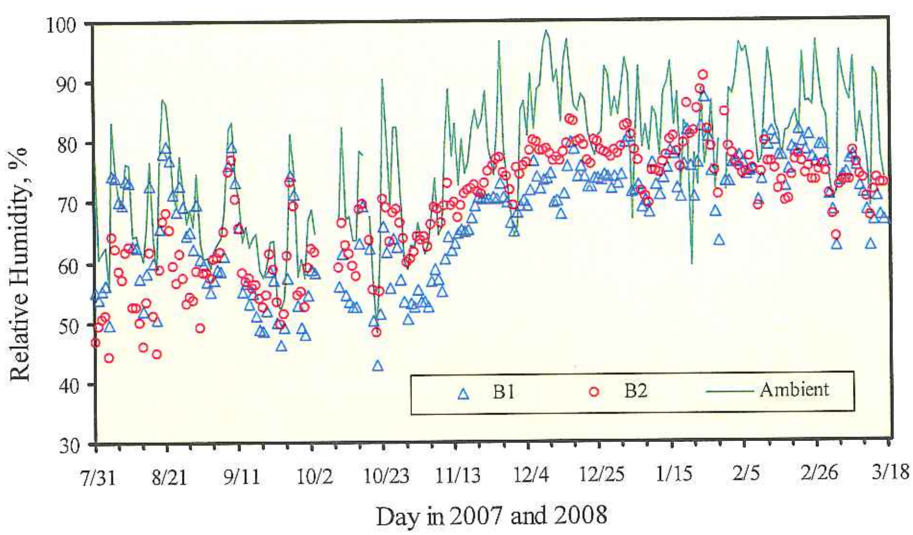

Figure 4. Daily mean relative humidity (%) of Barns 1 and 2, and ambient air.

Ammonia Concentrations and Emissions

The ADM ambient NH_3 concentration was 3.4 ppm (n=218 out of 230 days) and remained relatively stable throughout the entire measurement period (Figure 5). The ambient NH_3 concentration ranged from -3.9 to 12.0 ppm. The values were comparable to the previous studies conducted at the same site (Lim et al., 2007), and was relatively higher in warm weather. The ADM exhaust concentrations of both barns are also shown in Figure 5. The first week data (Test 1, August 1 to 6, 2007) was used as the baseline to compare the concentrations and emission rates between the two barns. However, the only exception to this baseline data was that the B2 bird population was already decreased. The period mean concentration values are reported in Table 4. The mean concentrations in the B2 exhaust streams were consistently lower than B1, except for the manure removal period. The concentration differences were not further discussed because the mitigation effectiveness is evaluated based on emission rate, and on a cross-barn comparison, especially when the barn inventories were different, which was part of the BMPs.

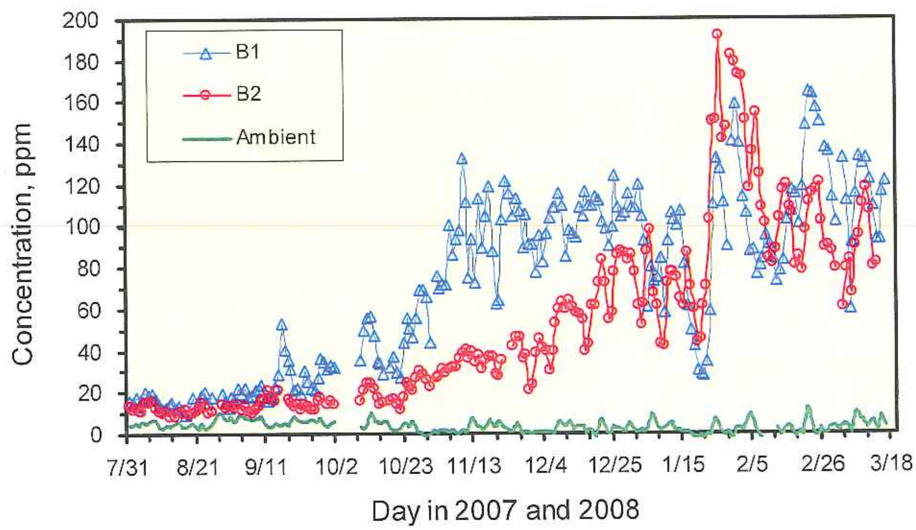

Figure 5. Daily mean NH_3 concentrations of Barns 1 and 2, and ambient air.

Table 4. Mean NH_3 concentration and emission rate of individual tests, and difference between the two barns.

Test	Date	NH_3 concentration, ppm			NH_3 emission, mg/s		
		B1	B2	Diff, %	B1	B2	Diff*, %
1	8/1-8/6	16.6	12.5	24.2%	2691	1691	37.3%
2	8/7-8/27	14.9	11.5	20.9%	2407	1485	37.6%
3	8/28-12/10	58.5	25.3	49.3%	3957	1026	71.8%
4	12/11-1/14	99.2	67.7	30.0%	5138	1904	63.9%
5	1/15-2/18	88.4	114	-35.0%	4732	3424	21.7%
6	2/19-3-17	122	93.1	23.1%	6249	2742	55.4%

* Calculated based on paired B2-B1 daily emission rate comparison.

The daily mean NH_3 emission rates ranged from 1092 to 8593 mg/s for B1, and ranged from 556 to 5499 mg/s for B2 (including partial data of first week), Figure 6. The ADM untreated NH_3 emission rates of B1 was 4376 mg/s, or 729 g $d^{-1}AU^{-1}$ (2.21 mg d^{-1} hen^{-1}). The effectiveness of the fiber-enhanced feed and BMPs was evaluated by comparing the barn emission rate (mg/s-barn), rather than the emission rate normalized to live-mass or per-bird basis. This is because the reduced number or layer bird per cage-area was implemented as one of the BMPs. However, the emission rates normalized to unit live-mass (g d^{-1} AU^{-1}) and per-animal basis (g d^{-1} hen^{-1}) were also reported in Tables 3 and 4. In the previous test with the same barn conducted in 2005 and 2006, the ADM untreated NH_3 emission rates of B1 was 480 g d^{-1} AU^{-1} (Lim et al., 2008a). As expected, these values were higher than a six-month summer to winter NH_3 emission of 92.8 g d^{-1} AU^{-1} for a new layer barn with manure belt (Sun et al., 2003).

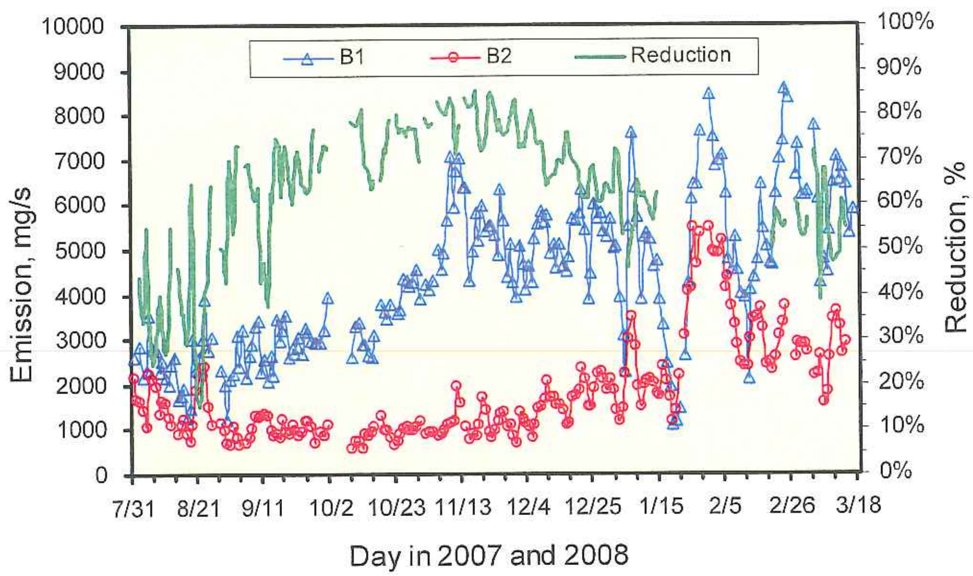

Figure 6. Daily mean NH_3 emissions of Barns 1 and 2.

<u>NH_3 Emission Reductions due to the Fiber-Enhanced Diet and BMPs</u>

The ADM NH_3 emission rates were 2691 and 1691 mg/s for B1 and B2, respectively, before the fiber-enhanced diet and all BMPs were implemented. The B2 NH_3 emission rate of Test 1 was 37% (mean of 5 paired emission rate differences) lower than B1, while the total live mass difference was 17% (B1=527 AU, and B2=435 AU). The lower emission values were most likely due to the lower number of birds per unit area. However, the difference in Test 1 was calculated from a small number of paired emission values, and the test lasted only 7 days in September, 2007, which is a very small portion of the eight-month test, thus the barn difference before the treatment was not used to correct or adjust the reductions in the following tests. Furthermore, the lower number of birds itself was part of the BMPs, thus the difference in Test 1 was not a true baseline.

The emission values of Tests 2 and 5 were not used to evaluate the mitigations, because a stabilizing period is expected before the diet and BMPs show effects, in Test 2. For Test 5, the manure was being removed from the barns.

The mean NH_3 emission rates of Test 3, when the effects of fiber-enhanced diet and BMPs had stabilized, were 3957 and 1026 mg/s for B1 and B2, respectively. The mean paired difference was 71.8% (n=90 out of 105 days, August 28 to December 10, 2007). The emission rate of B1 was consistently higher than B2, with a minimum difference of 38% on September 13, 2007, and a maximum difference of 86% on November 18, 2007. There was an upward trend of emission difference until late November 2007, which then decreased until the end of the test period. Since there are multiple mitigation techniques implemented as a combined effort to reduce NH_3 emission rate in the treated barn, and the barn airflow also changed, it is not known which factor contributed the most to the reductions on the trends.

The emission differences between the control and treated barns continued to decrease in Test 4, when the fiber-enhanced diet was discontinued, but the BMPs were kept as a mitigation practice to reduce NH_3 emission. The mean difference based on paired daily barn emission rates was 63.9% in this test period. Since the manure from previous fiber-enhanced diet was not removed immediately from B2, it is possible that part of the emission reduction was caused by the diet mitigation. However, the old manure was already covered by five weeks worth of new manure, and most of the NH_3 emission is expected to emit from the fresh manure. It is thus important to study the effects of only the BMPs when all manure was removed from both barns, which was the purpose of Test 6.

The mean paired emission differences between the two barns was 55.4% in Test 6 (Table 2). The paired daily NH_3 emission differences ranged from 39% to 72% (23 data points out of 28 days). Due to the lack of test replication and individual BMP tests, it is not known which BMP factor contributed the most to the NH_3 emission reduction. The emission rates were 6249 and 2742 mg/s for B1 and B2, respectively, for the test period of February 19 to March 17, 2008. These emission differences confirm the findings in Test 4, and the fact that the BMPs implemented in the treated B2 were sufficient to reduce the NH_3 emission rate by 55% or more, on a per-barn basis. The combined effects of manure drying fans, reduced crude protein, reduced chlorine, leak management, and lower bird density contributed to the overall lower emission rates in the treated barn.

The use of the 36 pit drying fans and the leakage management program lowered manure MC values in B2, Figure 7. The manure MC was similar, which was 31.8% and 29.3% for B1 and B2, at the beginning of tests. After the mitigation techniques were implemented, the manure was observed to be drier from early October to late December 2007, most likely due to the enhanced drying provided by the pit recirculation fans. The MC difference between the barns dropped down to 3.1% in late January 2008 when the manure was removed from both barns, which were then re-bedded with similar amount and source of manure from another barn. The drier manure in the treated B2, in Tests 3 and 4, helped to reduce NH_3 emission, because manure with higher moisture content is expected to release more NH_3 than drier manure piles. In Test 6 (February 19 to March 17, 2008), the manure sampling was conducted on February 27, 2008, and the manure MC of B2 was 18% lower than B1.

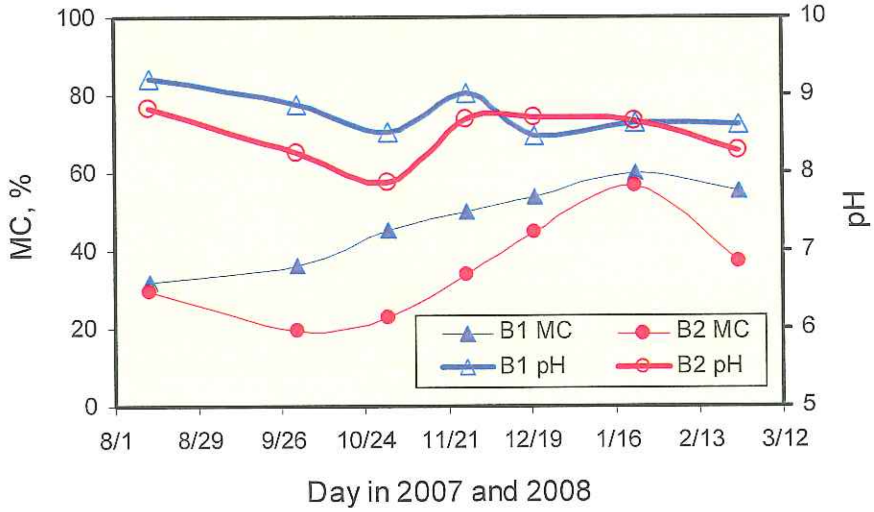

Figure 7. Mean Manure Moisture Content and pH Values of the Two Barns.

The other important mitigating BMPs were the increased feed fiber and reduced crude protein contents to reduce NH_3 emission. The results of the fiber analysis confirmed that the B2 feed fiber content was consistently lower than B1, until the normal feed ration was resumed after December 11, 2007, Figure 8. However, the mean feed crude protein contents of B2 was only lower than B1 at the first, third, and fifth sampling events, and were similar for the last two samplings, and was even higher than B1 for the November 27, 2007 samples, Figure 9. Even though the two composite feed samples each consisted of sub samples taken from each of the four feed conveyers of the barn, there was no replication, and the sample number was very low.

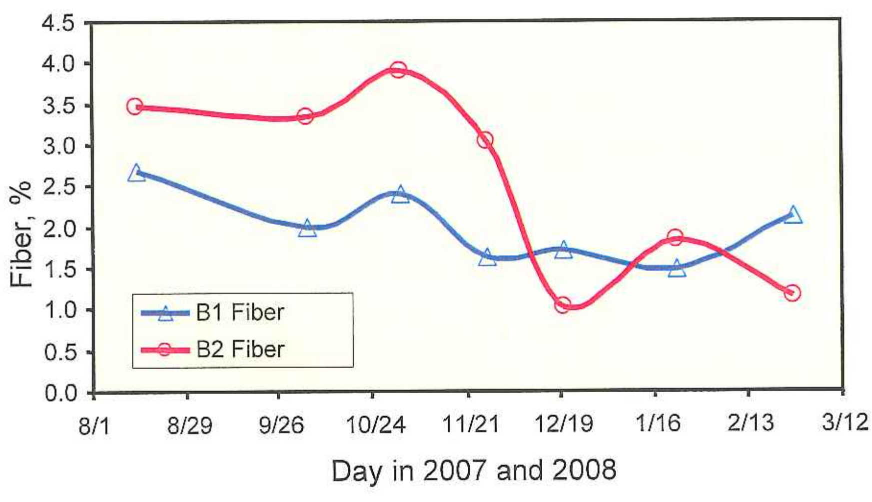

Figure 8. Mean Feed Fiber Contents of the Two Barns.

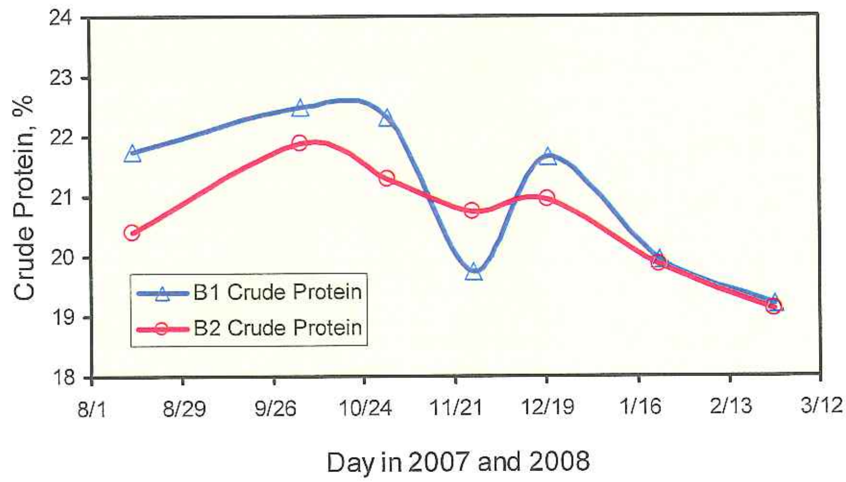

Figure 9. Mean Crude Protein Contents of the Feed of the Two Barns.

Conclusions

1. The ADM NH_3 emission rates were 2691 and 1691 mg/s for B1 and B2, respectively, before the fiber-enhanced diet and all BMPs were implemented in Test 1. The difference was 37%, which was assumed to be caused by the lower number of birds.
2. In Test 3, when the fiber-enhanced diet and BMPs were implemented and emission rates stabilized, the mean paired daily difference was 72% (n=90 out of 105 days, August 28 to December 10, 2007).
3. When the fiber-enhanced diet was discontinued, while keeping all the BMPs in Test 4, the NH_3 emission reduction averaged 64%, between December 11, 2007 and January 14, 2008. The reduction was not attributed entirely to the BMPs because of residual manure from the previous test in the treated barn.
4. The test of the BMPs was replicated in Test 6 and after manure removal and re-bedding, the mean paired emission difference was 55.4%.
5. The pit drying fans and the leakage management program successfully lowered the manure MC in the treated B2. The drier manure in Tests 3, 4, and 6, helped to reduce NH_3 emissions.

References

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